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TECHNOLOGICAL MATURITY OF ERTMS
ON THE READINESS OF ERTMS BASED SIGNALLING

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Appendix 1

Operational Maturity Issues

EXECUTIVE SUMMARY

This report contains an update of the Maturity study elaborated in 2008 and includes the main findings experienced during the various phases of the project up to date.

It also contains an assessment on the evolution of ERTMS based on the System Readiness Level of various projects and technical features. Experience gained by Denmark, Switzerland and other countries are taken into consideration.

The Danish Signalling Programme is progressing according the plan. The goals and scope remain unchanged. Thus, it is assumed that the planning methods applied and the organisation put in place covered all relevant aspects. This was only achievable by a detailed study of all factors of importance for this unprecedented project.

The factors to be considered for migrating to ERTMS/ETCS are different in every country. Thus, a global common strategy cannot be applied.

Maintaining transparency and traceability between operational scenarios, functional requirements and future system specifications prove to be a challenging task. Modelled scenarios sometimes become superseded by the maturing operational rules.

The report documents that ERTMS/ETCS has matured, it performs perfectly on lines but it still takes time to bring it to the stations/nodes.

Many projects are currently in the design and lab testing phase. A substantial gain on experience on the more complex applications (e.g. large stations, shunting) can be expected within the next 3-5 years.

Today ERTMS is used in 38 nations throughout the world. Thus, it can be stated, that ERTMS has become « the » global signalling standard.

The main reasons for the implementation of ERTMS are Punctuality, Safety (reduces the incidence and consequences of Signals passed at danger), Interoperability (greater mobility for trains across Europe), Capacity and Performance.

Introduction of ERTMS has already facilitated the cross-border movements of freight trains in Europe and lead to enhancement of the reliability, quality and competitiveness of the freight train operator’s services.

1. INTRODUCTION

The Dutch Ministry of Infrastructure and the Environment has initiated a process for introduction of ERTMS. The current process is described in the "ERTMS Railway Map". For the continuous updating of the planning experience and lessons learnt outside the Netherlands shall be taken into consideration. The approach to and experience with the implementation of ERTMS in Denmark, Belgium and Switzerland is of particular interest for the programme envisaged in the Netherlands.

The implementation of ERTMS in Denmark is on-going. In 2008 the implementation plan for a complete replacement of the existing signalling systems on the Danish railway network was approved. Following a tendering phase contracts with suppliers for delivery, installation and maintenance were signed early 2011.

A comprehensive package of documents dealing with all aspects related to the implementation of ERTMS was prepared for the Danish Infrastructure Manager, Banedanmark. One of these documents, "Technological Maturity of ERTMS" dealt with assessment of the readiness of ERTMS based signalling. The report was prepared in 2008 using the "System Readiness Level" methodology.

This report contains an update of the study prepared for Banedanmark with addition to:

a) The main findings from the Danish Signalling Programme regarding the technical maturity, supplemented with relevant developments in other countries
b) Overview on the maturity of "other" technical aspects as (possibilities for) enlargement of capacity compared to the current system, ERTMS on yards, On-line Key Management, GSM-R capacity, evolution of European standardisation, railway capacity considerations, ERTMS Regional, level crossings, etc.

The study deals with conventional rail in the same way as was the case for the initial study prepared for Banedanmark as Banedanmark's network only comprise conventional lines.

Section 2 contains a review of the main phases of the Danish Signalling Programme with focus on the development in the period 2008 – 2013. In the subsequent section 3 the maturity of ERTMS is assessed bringing the information contained in the initial report from 2008 up to date. Throughout the report implications and recommendations for the Dutch ERTMS process are included wherever applicable.

1.1 Abbreviations

Throughout the report the following railway and signalling abbreviations have been utilised:

Abbreviation	Explanation
ATC	Automatic Train Control
BAFO	Best and final offer
DBM	Design build maintain
CR	Change Request
DMI	Driver machine interface
DMU	Diesel Multiple Unit
DSB	Danish State Railways
EMC	Electromagnetic Compatibility
EMU	Electric Multiple Unit
ERTMS	European Rail Traffic Management System
ESR	Emergency Speed Restriction
ESTW	Electronic Interlocking

Abbreviation	**Explanation**
ETCS	European Train Control System
EVC	European Vital Computer
FRS	Functional Requirement Specification
GPRS	General Packet Radio Service
GSM-R	Global System for Mobile Communications – Railway application
HSL	High Speed Link
IP	Internet Protocol
IXL	Interlocking
KMS	Key Management System
LEU	Lineside Electronic Unit
MA	Movement Authority
MPLS	Multiprotocol Label Switching
OBU	Onboard Unit
PKI	Public key infrastructure
PPP	Public Private Partnership
RBC	Radio Block Controller
SBB	Swiss Federal Railways
SPAD	Signal passed at danger
SR-75	Banedanmark Rule book SR-75
SRL	System Readiness Level
SRS	System Requirements Specification
STM	Specific Transmission Module
TEN-T	Trans-European Transport Network
TCC	Train Control Centre
TMS	Train Management System
TRU/JRU	Train Recording Unit / Juridical Recording Unit
TSR	Temporary Speed Restriction
UNISIG	Union Industry of Signalling (a UNIFE work group)
V&V	Verification and Validation
VDE	German unification transport projects

2. REVIEW OF THE DANISH SIGNALLING PROGRAMME

The scope of the Danish Signalling Programme is a total replacement of all Banedanmark's signalling assets. The introduction of ETCS is a part of the programme which includes introduction of a wide range of new signalling system components.

The Dutch Government has decided to introduce ERTMS in phases. The programme has identified four scenarios for the introduction on the infrastructure and will begin with the rolling stock. Additional work will be needed to figure out in detail to what extent experience from the Danish Signalling Programme may be relevant for the Dutch ETCS programme.

The Signalling Programme in Denmark is implemented in a number of phases. The following sections contain the main experiences of each of these phases with a focus on the issues of relevance for the Dutch ETCS programme.

2.1 Strategic Study

As the strategic decision of introducing ETCS on the Dutch railway network has been made there is no need for a review of this phase of the Signalling Programme.

2.2 Programme Phase

Banedanmark performed the Programme Phase in 2007 and 2008. The aim of the Programme Phase was to carry out the necessary investigations and prepare the necessary document for the parliamentary decision for the investment required for the replacement of all Banedanmark's signalling assets.

As part of the process all relevant aspects were analysed for such an unprecedented move in order to demonstrate the feasibility of the programme. The following main aspects were investigated:

- Overall technical solution and scope: ETCS Level 2 without optical signalling on the Fjernbane, CBTC on the S-Bane
- Initial considerations on operation of a railway without optical signalling
- How to perform migration for infrastructure and rolling stock
- The need for an early deployment line to iron out issues before rolling out over the whole network and the use of a test laboratory to prepare the systems for deployment on the early deployment line.
- Preparation of a realistic time schedule for the realistic design and roll-out phases
- Elaboration of a procurement strategy reflecting the size of the programme and aiming at getting the most value for money
- Identification of the kind and scope of business changes needed within Banedanmark caused by the implementation of the Signalling Programme and how to address them
- Systematic risk analysis
- Preparation of a programme budget covering all costs related to the implementation of the Signalling Programme

The goals of the Programme Phase were fully realised. No unexpected important issues have popped up so far during the continued implementation of the Signalling Programme. Thus, it is assumed that the Programme Phase covered all relevant aspects.

The preparation of a credible budget proved to be the main challenge, as no project comparable in size and scope had been implemented before in any country. The available cost examples were all based on much smaller projects. The envisaged impact of economy of scale could not be

assessed. The size of the programme led to fierce competition during the tender phase leading to final bids substantially below the budget prepared during the Programme Phase.

The key success factor for realising the goals of the Programme Phase was the setting up of an integrated organisation comprising spearhead staff from Banedanmark and international experts with different skills, backgrounds and experiences. The staffing mixture paved the way for covering all relevant aspects without leaving gaps. The integrated organisation enabled open discussions on all aspects of the Signalling Programme without limitations caused by varied business interests of the different participants.

Ramboll (DK) and Emch+Berger (CH) were consultants to Banedanmark for the assignment.

2.3 Operational Preparations

While waiting for the political approval of the Signalling Programme investment and procurement of consultancy for the upcoming phases, the Signalling Programme launched a project with the task of preparing a formal description of the future railway operations and to initiate the preparation of new operational rules. During the previous phases it was realised that the preservation of the current national operational rules should be avoided as far as these operational rules could deter the implementation of standard technical solutions.

The operational scenarios that constitute the running of the Danish railway were identified, modelled and detailed to a level indicating the message flows that make up the scenarios.

On the basis of the modelled scenarios it could be identified whether an action were attributed to a person or a technical system, and thus where an action called for an operator action or a technical functionality. The message flow between persons and technical systems indicated the necessary operational rules.

The modelled scenarios were put into context by an operational concept in the form of a clear text description of how the railway currently is operated with line side signals as compared to the expected future operation with an ERTMS level 2 baseline 3 system without line side signals. This operational concept in combination with the modelled scenarios gave confidence that the captured description of the future railway operations was complete as far as possible from information available at the time. Thus, it could form the basis for preparation of both functional requirements and early drafts of the new operational rules.

Maintaining transparency and traceability between operational scenarios, functional requirements and future system specifications have proven a huge challenge. The modelled scenarios have been superseded by the maturing operational rules. The experience gained during the Generic Design Phase (section 2.5) shows that careful documentation of design decisions and continuous maintenance of the operational concept can ease the assessment of design suggestions.

2.4 Procurement Phase

Following the political approval the implementation of the Signalling Programme was initiated. The first phase was the Procurement Phase which had the following goals:

- Elaboration of a detailed plan for implementation of the procurement strategy prepared during the Programme Phase
- Preparation of tender documents
- Carrying out of the procurement process
- Negotiation and signing of contracts

Following an assessment of the opportunities and risks of large lots which has been unknown to the signalling industry so far it was decided to carry out the tendering in the following four main lots:

- Fjernbane Infrastructure East

- Fjernbane Infrastructure West
- Fjernbane On-Board
- S-Bane Infrastructure and On-Board

The activities were initiated in September 2009 and the contracts were signed in December 2011 and January 2012. The procurement was carried out in accordance with the EU directives with a prequalification followed by a two stage tendering phase comprising a first negotiation tender and a best and final offer (BAFO). All tenders were for design, build and maintain contracts. The six UNISIG suppliers were prequalified and submitted tenders. Banedanmark has simultaneously initiated other projects which deal with other aspects needed in order to realise the objectives of the abovementioned four main projects. These projects covered amongst others:

- GSM-R data
- Fixed Transmission Network (laying down of necessary fibres, creating back loops and converting the fibre network to a MPLS network)
- Enterprise Service Bus (to simplify the interfacing of the new signalling system to none safety and/or time critical systems)
- Civil Works for the Traffic Control Centres
- Training of personnel
- Maintenance Preparation Coordination between projects and the bas organisation

The Procurement Phase is seen as a full success as the main result has been that in all four lots, the contracted prices are significantly lower than budgeted and unit prices lower than seen in the industry hitherto. Despite the huge complexity of the procurement, the phase could be completed almost on time.

The following success factors have contributed to this result and may be applied to the Dutch ERTMS programme:

- Large lots with committed funding have been defined to allow for industrialising the signalling work and generate economy of scale benefits.
- Opening up the competition as far as possible, by avoiding special Danish requirements to the new signalling system and by allowing the suppliers to use their own processes and methods for implementation.
- The requirements specification has been set up at functional level, allowing the suppliers to make best use of their existing products.
- The risks have been carefully distributed between the suppliers and the customer. Attention has been given to put only those risks on the suppliers that the suppliers can actually assess and manage. The collaboration in the area of risk is still in its infancy and currently the majority of identified risks are still assigned to the customer.
- The negotiations following the submission and evaluation of the first negotiation tender resulted in significant improvement of the tender material by removal of potential ambiguities. This paved the way for the bidder’s sharp price calculation in the BAFO.
- Maintenance has been included in the contract scope, thus incentivising the suppliers in delivering a system with optimum life cycle costs and fulfilment of the RAMS requirements throughout the systems’ lifetime.
- An integrated organisation comprising of Banedanmark staff and international experts was divided into four core teams, one for each lot with support at programme level for strategic, administrative, legal and political tasks.
- Flat hierarchies and strong support from upper management allowed for timely decisions.

Due to the long time period until the Signalling Programme is completed, careful contract Management will be crucial in order to limit the scope of Change Orders and mitigation of the associated risks.

2.5 Generic Design Phase

The Generic Design Phase was initiated immediately after contract signature. The Generic Design Phase is divided into two sub phases for Conceptual Design and for Preliminary Design. The Conceptual Design sub phase was completed in the autumn 2012. The Preliminary Design sub phase is planned to finish in the autumn 2013.

The main goals of the Conceptual Design sub phase were:

- All plans for project management and technical processes in place

  Clarification of the customer requirements. Customer and suppliers go through the customer requirements in order to identify ambiguities of requirements and ensure a common understanding of all requirements. Further, the test required for verification of the fulfilment of each requirement should also be agreed upon.

The main goals of the Preliminary Design sub phase are:

- Preparation and review of the suppliers' system and subsystem requirements
- Preparation and review of additional design documents describing the system from the supplier
- Provide Generic Application Safety Cases for the main components
- Joint design completed (the joint design is handling all design issues involving several suppliers)
- Interface control documents completed
- Customer deliveries serving as a design basis delivered (e.g. ETCS braking curves, national values)
- Enabling projects like GSM-R data, Fixed Transmission Network, Enterprise Service Bus, Civil Works for the Traffic Control Centres which have been started in parallel to the Procurement Phase and the Generic Design Phase.

The overarching principle is that no major generic design issues are left open at the end of the Generic Design Phase.

Based upon experience gained during the Generic Phase it is recommended to put special attention to the following issues by the continued preparation of the Dutch ETCS programme:

- The suppliers shall have sufficient manning to comply with the time schedule during the design phase in order to avoid delays in submission of design documents.
- The suppliers shall ensure necessary coordination between their front and back offices in order to avoid conflicts of interests which may lead to delays.
- Timely launching and coordination of all project needed (section 2.4) in order to avoid delays in the commissioning of the main project.
- Attention to the maintenance preparation shall be an integrated part of the Generic Design Phase activities. This can contribute to the most attractive life cycle costs.
- Considerable management efforts are needed for projects in a multi supplier environment with a need for joint design activities.

- The availability of the supplier's software development plans and roadmaps for core signalling areas like ETCS and TMS are keys to monitor progress on software development and planning of effective track/train integration.
- Design of interfaces to external systems may time consuming as the necessary information may not be available on a short notice.
- As the infrastructure is used for the ongoing operation during the implementation period it may undergo changes e.g. due to renewal. This may change the design basis during the project period. Resources are needed to ensure that the correct infrastructure data are available for the project.
- Clear division of responsibilities is required in a project environment involving many parties without losing the benefits of a consensus culture created by having parties involved working together at the customer's premises.
- Ensure that all processes used for the project activities comply with the project's industrial nature which may differ considerably from the customer's other activities and previous projects due to the scale of the Signalling Programme. Sufficient management effort shall be allocated to operate a large scale programme
- The involvement of the customer's base organisation is a key for the realisation of the project objectives. Resources shall be made available to ensure that this involvement can take place.
- Completion of operational preparation is time consuming due to complexity of specific issues, e.g. shunting, joining and splitting and the activation of level crossings, the need for comparison with the existing customer requirements and details on the supplier's products. These issues constitute risks for a timely software development process. In the Dutch context it should be analysed, if it is preferable to prepare open functional specifications and to make decisions regarding such issues together with the selected suppliers, or to settle those points to as wide extent as possible before the procurement phase. It should be investigated with all potential bidders how the proposed operations fit with their products. More details on such issues can be found in Appendix.
- Both the infrastructure project and the onboard shall be properly rooted, including ownership, at an early project preparation stage in order to ensure that sufficient resources are allocated to all projects and that the focus can be kept on the planned activities.

Business agreements between the a signalling programme and the main train operator(s) shall be completed early during the project preparation in order to ensure that the train operator(s) can provide the necessary contributions in accordance with the time schedule. For the Dutch project it is recommended at an early stage to investigate this aspect of the relationship between ProRail and NS.

The Signalling Programme has dealt with the above mentioned issues. Considerable efforts have been used to deal with these challenges without endangering the time schedule and project goals.

2.6 Early Deployment Phase

The main goals of the Early Deployment Phase are:

- Solve outstanding generic design issues
- Perform application design for the early deployment line
- Perform software development
- Perform production and installation for the early deployment line, both Supplier and Customer deliveries

- Perform testing and commissioning
- Train staff in utilisation and maintenance of the new signalling system, including the new operational rules
- Perform trial runs
- Get safety approvals and generate internal generic system catalogue (Type approvals)
- Perform supervised commercial operation
- Perform the reliability demonstration test.
- Prepare and perform handover to the base organisation
- Get permission to continue with the rest of the roll-out lines.
- Train the installation crews and start the optimisation of installation processes for the roll-out.

The Early Deployment Phase will be the moment of truth for both the suppliers and the customer. As the Early Deployment Phase will start towards the end of 2013, it is premature to draw lessons from this phase, but it is already possible to conclude the following on the scope of the phase:

The Early Deployment Phase will cause a major shift from generic design to much more specific activities as listed above. This will cause changes to the project organisation and the working processes, which must be prepared before the start of the phase. The challenges identified during the Generic Design Phase (section 2.5) will be taken into consideration by this work

The coordination with other projects working on the same part of the infrastructure impose another challenge. The new signalling system will be installed on an infrastructure in operation where other changes and renewals will be carried out in parallel. For each line access to the updated design basis will be needed for the new signalling system. Further, coordination of the actual work is required. The careful coordination between different projects will be needed in order to avoid possible project delays and to minimise the cost of changing design late in the project.

3. ASSESSMENT OF MATURITY

3.1 Introduction

The review of the technological maturity of ERTMS is a critical point for projects with strategic nature, because the contribution to project risk is one of the major drivers of migration planning. Therefore, a well-documented, understandable and straightforward methodology must be used to evaluate the technological maturity of ERTMS.

3.2 Methodology

The methodology is based on the "System Readiness Level" method[1] in a modified form taking into account that the scope is not only the development phase up to the system validation, but also the later stages until the productive use of the technology.

The first step of the evaluation is to collect information on the status of the current ERTMS projects. This information is used for evaluation of the System Readiness Level of the different items constituting the ERTMS technology. A first evaluation is carried out at the current date. Further evaluations are performed at future dates in order to reflect the expected development and roll-out of ERTMS. For each ERTMS project a separate sheet describing the project basis (scope, extent, baseline/SRS version etc.), goal and status will be prepared and examined.

In addition it is necessary to assess the evolution of the ERTMS baselines, as the availability of future functionalities depends on the evolution of the baselines.

3.2.1 *Maturity of Signalling*

Special focus is on the ERTMS part of each project as the general part of a project is not necessarily indicative for the core aspects of a Danish signalling project.

ERTMS and specifically ERTMS Level 2 is regarded as risky business by a number of people with a non-signalling context knowledge. For the pilot projects that started more than 10 years ago this was indeed the case as the entire system by nature was on a conceptual stadium and operation less defined in the pilot phase. However, it must also be kept in mind that a number of central signalling design issues are generic issues related to the Safety aspects. They are inherently complex and challenging regardless of choice of standards and methods. Defining and proving the Safety functions of a signalling system is a challenging task no matter which set of standards and rules form the basis. So embarking on the replacement of signalling, system designers will meet most of these challenges no matter which strategy is chosen for replacement.

Most national rules including the Danish SR-75 were developed over a period of more than 100 years on the basis of specific safety related events, leading to a complex "layer on layer" rulebook. Within the national frame signalling design, safety aspects and not least interface aspects are proven to be very complex.

In this context a simplifying approach as the choice of ERTMS level 2 without lineside signals and a design with uniform interfaces between interlockings, train control and rolling stock can be seen as a substantial project risk reduction factor.

3.2.2 *System Readiness Scale*

The used scale of System Readiness Levels (SRL) is the following:

[1] "Technology readiness Level" method mandated by US Department of defence and UK Ministry of Defence as well as major industrial companies

Level	*Definition*
0	No agreed project specific specification available
1	Agreed project specific specification available, no product development work undertaken
2	Product development work ongoing
3	Laboratory tests ongoing
4	Test operation ongoing
5	Early deployment* being implemented
6	Early deployment* operation going on successfully
7	Productive system** being implemented
8	Restricted productive operation** going on
9	Full productive operation** going on successfully

Notes:

* *An early deployment is a project aiming at resolving teething troubles and getting familiar with the ETCS operation. In such a project, a certain level of troubles is accepted.*

** *A productive system or a productive operation is a project aiming at a trouble-free operation under full load, which is expected to run smoothly from day one.*

The system readiness values are to be commented and justified, as there will be a number of caveats and special cases to be handled, e.g. incomplete functionality, insufficient performance, delays in implementation, provisional workarounds etc. If an implementation of an ERTMS item is part of a project that has suffered from major delays, major cost overruns or incomplete functionality, it will be duly commented. If another implementation is available, the level of this other implementation will be taken up, with comments regarding the delayed implementation.

The following aspects of ERTMS are to be evaluated:

A. ETCS Level 1 application with lineside signals and simple junctions and stations
B. ETCS Level 1 application in pure cab-signalling mode
C. ETCS Level 1 application on medium and large stations
D. ETCS Level 1 Limited Supervision
E. ETCS Level 2 application on simple lines and simple junctions, uniform traffic
F. ETCS Level 2 application on simple lines and simple junctions, mixed traffic
G. ETCS Level 2 application on simple stations with and without shunting mode
H. ETCS Level 2 application on medium stations with and without shunting mode
I. ETCS Level 2 application on large nodes with and without shunting mode
J. ETCS Level 2 application on lines with level crossings
K. ETCS Level 2 application on lines with conventional signalling
L. ETCS Level 2 and GSM-R-end-to end interface at a state border
M. ETCS Level 3/Regional on rural lines, with and without train coupling/splitting
N. ETCS Level 3 application on main lines with and without junctions/stations
O. Evolution of ERTMS technology: Unified braking model
P. Evolution of ERTMS technology: Cold movement detection/Start of Mission.
Q. Evolution of ERTMS technology: GSM-R for dense traffic
R. Evolution of ERTMS technology: Merger of interlocking and RBC
S. Evolution of ERTMS technology: Availability of specifications and products for baseline 3.

T. ETCS Level 2/3 application with Key Management System (KMS) complemented by online and PKI secured update of keys.

The scope of an ERTMS project review sheet is:

Aspect	*Description*
Perimeter	Line (from - to), length
Line categorisation	Simple/complex, main/rural, dedicated or mixed use, line speed, level crossings, ETCS level
Operational characteristics	Uniform/mixed traffic, number of trains daily, min headway
Comparison to Danish network	In relation to sections or nodes of the Danish network
Rolling Stock	Number of rolling stock fitted/to be fitted (types/numbers)
Interlocking	Number of interlockings/objects controlled
Scope	ETCS overlay, re-signalling, increased capacity/punctuality
Project Timeline	Start and end date
Project Status	Planning, test, commissioning, restricted operation, full operation
Project Baselines	SRS version, national/specific requirement
Measures re. capacity	Measures aimed at measures re. capacity
Measures re. ERTMS baselines	Measures aimed at handling measures re. ERTMS baselines
Project comments on readiness	Project related comments relating to the readiness levels of ERTMS items

3.2.3 *Capacity Considerations*

As there are widely different opinions on the effects of ETCS on capacity, a separate chapter is dedicated to assess the effects of ETCS on capacity. The assessment will be based on international research results as well as checked against the same projects that are considered for system readiness.

3.3 ERTMS Projects

In this chapter the data collected from the reference projects are presented along with the assessment of system readiness level on the basis of each individual project.

Project Aspect	*Statement*
#1	**Austria: Northern Brenner Access Line**
Perimeter	Kundl – Baumkirchen 37.4 km of new line mainly in tunnel and approx. 45 km of the parallel existing line.

Project Aspect	*Statement*
Line categorisation	Main lines for mixed traffic. Several crossovers from the existing to the new line, existing stations on the existing line. ETCS Level 2 only on the new line. Overlay of ETCS Level 2 over existing signalling on the existing line.
Operational characteristics	Mixed passenger and heavy freight traffic. Maximum speed 200 km/h on the new line, 160 km/h on the existing line. 400 trains a day on both lines together.
Comparison to Danish network	Storebælt and Oeresund
Rolling Stock	N/A
Interlocking	5 existing relay interlockings and 5 electronic interlockings.
Scope	High capacity and high speed for mixed traffic
Project Timeline	2007 - 2013
Project Status	Commercial operation (04/2013)[2]
Project Baselines	N/A
Measures re. capacity	To be developed
Measures re. ERTMS baselines	N/A
Project comments on readiness	The system readiness level for ETCS level 2 in stations and overlay on existing signalling can be set to 9.
#2	**Austria/Hungary: Vienna – Budapest**
Perimeter	Vienna-Hegyeshalom (Austria) 65 km Hegyeshalom-Budapest (Hungary) 180 km
Line categorisation	Double track main line Overlay of ETCS Level 1 on existing signalling, partially renewal of Interlockings
Operational characteristics	Mixed traffic Maximum speed 160 km/h
Comparison to Danish network	Nyborg – Middelfart
Rolling Stock	13 locomotives
Interlocking	N/A

[2] to be confirmed by ÖBB n/a

Project Aspect	*Statement*
Scope	Interoperability and train protection on international corridor.
Project Timeline	2000-2005
Project Status	In commercial service
Project Baselines	Part of line originally built as trial site based on SRS 2.0.0. Upgraded to SRS 2.2.2
Measures re. capacity	N/A
Measures re. ERTMS baselines	N/A
Project comments on readiness	ETCS Level 1 application with lineside signals and simple junctions and stations ETCS Level 1 application on medium and large stations Can be set at readiness level 9 based on this project
#3	**Switzerland : Mattstetten – Rothrist**
Perimeter	Mattstetten – Rothrist, 45 km
Line categorisation	Main line with simple layout, double track and one junction, no stations, no level crossings. ETCS Level 2
Operational characteristics	The line is used for passenger and freight traffic. Due to the safety concept in tunnels, passenger trains run during the day and freight trains during the night. Passenger trains: 240 per day at a maximum speed of 200 km/h and headway of 2 minutes. Freight trains: 30 per day
Comparison to Danish network	The proposed new line Copenhagen – Ringsted would be a comparable line
Rolling Stock	Retrofitted stock until 2012: approx. 850 trains including passenger, freight locomotives, tilting trains, German (ICE1) and Italian (ETR610) high speed trains, control trailers and diesel vehicles for maintenance, diagnostics and rescue They are also used for the Lötschberg Base Tunnel.
Interlocking	1 interlocking, 1 RBC, 5 switches, 196 balise groups, 240 axle counters
Scope	High speed with high capacity
Project Timeline	2002 - 2007
Project Status	Full commercial operation at 200 km/h since December 2007

Project Aspect	*Statement*
Project Baselines	“Swiss” baseline for Neubaustrecke and Lötschberg tunnel: SRS 2.2.2 and a set of change requests of Subset 108v110, no national functions. Planned for upgrade to SRS 2.3.0d for alignment with Gotthard base line.
Measures re. capacity	Short block distances. Optimisation of braking curves, the original braking curves proposed by the supplier were so flat that a reasonable operation would have been impossible. No use of service brake deceleration curve and service brake intervention curve.
Measures re. ERTMS baselines	N/A
Project comments on readiness	This project shows that ETCS level 2 for simple lines with simple junctions have reached system readiness level 9, as it works reliably under heavy traffic.
#4	**Switzerland: Gotthard Base Tunnel**
Perimeter	Gotthard Base Tunnel, 65 km
Line categorisation	Main line with double track, one station and one complex junction. ETCS Level 2 without lineside signals
Operational characteristics	High-capacity mixed traffic. Passenger trains: maximum speed 250 km/h. 1 – 2 passenger trains per hour per direction. Freight trains: Maximum speed 160 km/h, headway 3 minutes. 6 freight trains per hour per direction. Deployment of ETCS Level 2 in stations close to tunnels for optimised feeding (e.g. overtaking of freight trains) into the tunnel.
Comparison to Danish network	The Great Belt crossing would be a comparable section, however the level of freight traffic is much higher in the Gotthard Base Tunnel
Rolling Stock	Further retrofit of existing rolling stock (beyond the already 850 trains) to occur along further operational needs for this line.
Interlocking	4 interlockings, 2 RBCs, 39 switches, 261 balise groups, 410 axle counters, 12 hot box detectors
Scope	High speed and high capacity with truly mixed traffic.
Project Timeline	Start date for railway equipment: 2003 End date: 2016
Project Status	Installation and lab testing
Project Baselines	SRS 2.3.0d

Project Aspect	*Statement*
Measures re. capacity	Short block distances. Optimisation of braking curves, the original braking curves proposed by the supplier were so flat that a reasonable operation would have been impossible. No use of service brake deceleration curve and service brake intervention curve.
Measures re. ERTMS baselines	The project will be faced with technology changes due to the opening in 10 years. The contract contains provisions for handling technology changes.
Project comments on readiness	This is the first Swiss project containing complex operational patterns for ETCS level 2 in a station. The current system readiness level for this item can be set to 3. This project will be faced with the same problems regarding the functionality and upgrade path of SRS 2.3.0 as the Banedanmark signalling programme.
#5	**Switzerland: Lötschberg Base Tunnel**
Perimeter	Frutigen – Lötschberg – Visp: 42 km
Line categorisation	Main line with simple layout, single track partly double track and two junctions, no stations, no level crossings. ETCS Level 2 without lineside signals
Operational characteristics	The line is used for passenger and freight traffic. Trains per day: 40 passenger at a maximum speed of 250 km/h, 110 freight trains at a speed of 100 km/h 3.5 min headway for freight trains
Comparison to Danish network	The proposed new line over the Fehmarn Belt
Rolling Stock	Retrofitted stock until 2012: approx. 850 trains including: 119 passenger locomotives 199 freight locomotives 44 Swiss tilting trains, German (ICE1) and 9 Italian (ETR610) tilting trains 19 German high speed trains 130 control trailers 16 diesel trains, for maintenance, diagnostics and rescue New stock to be fitted: 14 Italian tilting trains
Interlocking	2 interlockings, 1 RBC, 3 switches
Scope	High speed with high capacity
Project Timeline	2001 – 2007

Project Aspect	*Statement*
Project Status	Commercial operation at 250 km/h for passenger trains since 2007
Project Baselines	“Swiss” baseline for Neubaustrecke and Lötschberg tunnel: SRS 2.2.2 and a set of change requests of Subset 108v110, no national functions. Planned for upgrade to SRS 2.3.0d for alignment with Gotthard tunnel.
Measures re. capacity	Short block distances. Optimisation of braking curves. No use of Service Brake Deceleration Curve and Service Brake Intervention Curve. Reversing function (Emergency propelling) is implemented for the evacuation of the tunnel.
Measures re. ERTMS baselines	None
Project comments on readiness	Project indicates Readiness level 9 for ETCS level 2 on simple lines with simple junctions.
#6	**Switzerland: ETCS Level 2 in large nodes**
Perimeter	This activity has the status of a study inside Swiss Federal Railways in collaboration with the UNISIG companies. Its aim is to increase the capacity of larger station areas in the network (case study: Bern station).
Line categorisation	Nodes (Freight and passenger junction/station areas)
Operational characteristics	Headways of 90 seconds with low speed
Comparison to Danish network	Copenhagen Central station area
Rolling Stock	-
Interlocking	-
Scope	Short headways in nodes and junctions
Project Timeline	Study started 2001, End not defined
Project Status	study completed, currently no deployment
Project Baselines	Standard functions of ERTMS
Measures re. capacity	Measures Aimed at Measures re. capacity - short distance of MA points - high capacity RBC and interlocking - high capacity GSM-R cell
Measures re. ERTMS baselines	-

Project Aspect	*Statement*
Project comments on readiness	The system readiness level for the use of ETCS level 2 in stations is currently 1.
#7	**Switzerland: Limited supervision**
Perimeter	3000 km of lines (95% of the whole SBB-network)
Line categorisation	Main lines and secondary lines with complex stations.
Operational characteristics	High density, mixed traffic., speed up to 160 km/h
Comparison to Danish network	Several lines
Rolling Stock	1500 to be fitted
Interlocking	500 interlockings. About 100'000 controlled objects
Scope	To make the whole SBB network interoperable at minimum cost. As Switzerland has a lot of cross border operation, interoperability is a major issue for SBB and they have been seeking a cheap way to ensure technical interoperability without replacing their existing relay Interlockings which have been maintained to a very high standard that ensure many years of operation.
Project Timeline	2007 - 2015 (Corridor A) / 2017 (whole network)
Project Status	Roll out and shadow train runs (test trial) are ongoing.
Project Baselines	SRS 3.3.0. include Limited Supervision functionality.
Measures re. capacity	Values of braking curves will become "national values"
Measures re. ERTMS baselines	N/A
Project comments on readiness	This project indicates that Level 1 Limited Supervision is currently at System readiness level 8/9. Around 2015 this will rise to readiness level 9 upon commissioning of the first line(s) on the basis of 3.3.0 specification.
#8	**The Netherlands: Betuwe Route**
Perimeter	Rotterdam – Emmerich - German border, 160 km
Line categorisation	Double track dedicated freight line, ERTMS level 2 without lineside signals.
Operational characteristics	Uniform traffic, max speed 120 km/h

Project Aspect	*Statement*
Comparison to Danish network	International Freight operation on Danish part of Corridor B (Peberholm-Padborg)
Rolling Stock	49 locos in service, number is growing
Interlocking	1 Interlocking, 78 points, 305 AC track circuits, 99 universal object controllers 78 point object controllers 3 RBC's, 693 fixed balises, 66 switchable balises, 18 LEUs.
Scope	New built dedicated International freight line, complete ERTMS level 2 signalling.
Project Timeline	2003-2007
Project Status	In commercial service
Project Baselines	SRS 2.2.2 being upgraded to baseline 2.3.0d.
Measures re. capacity	N/A
Measures re. ERTMS baselines	None
Project comments on readiness	This project shows that ETCS level 2 for simple lines with simple junctions have reached system readiness level 9. Main obstacle has been onboard fitment of Freight Locomotives and EMC issues related to the influence between 25 KVAC electrification and 1500 VDC tracks.
#9	**The Netherlands: HSL South**
Perimeter	Amsterdam Central – Schiphol – Rotterdam - Antwerp (-Brussels), 100 km
Line categorisation	High speed line ERTMS level 2 with possible whole line fall-back to a simple ERTMS level 1(with reduced lineside signals)
Operational characteristics	Uniform high speed traffic, 300 km/h
Comparison to Danish network	None, but general system aspects are valid
Rolling Stock	
Interlocking	N/A
Scope	New built High speed line with ETCS level 2. Design build maintain (DBM), public private partnership (PPP) scheme under direct government control, handed over for operation at ProRail.
Project Timeline	1999-2008
Project Status	commercial service

Project Aspect	*Statement*
Project Baselines	SRS 2.3.0
Measures re. capacity	N/A
Measures re. ERTMS baselines	None
Project comments on readiness	This project shows that ETCS level 2 for simple lines with simple junctions have reached system readiness level 9.
#10	**Great Britain: Cambrian Line**
Perimeter	Shrewsbury- Aberystwyth/ Pwllheli, 215 km
Line categorisation	Single track with passing loops, rural line, 123 level crossings ETCS level 2 with no lineside signals. Early deployment Scheme for the National ERTMS programme in the UK.
Operational characteristics	Low capacity, Mixed traffic
Comparison to Danish network	Comparable with Roskilde-Køge-Næstved and Aalborg-Frederikshavn
Rolling Stock	17 DMU and, 4 locos (for transport to/from possessions and maintenance)
Interlocking	13 interlockings exchanged with 1 interlocking and RBC at Machynellth. Traffic Control Centre also at Machynellth. Approx. 75 Axle counter sections.
Scope	Resignalling: New Interlocking, RBC and Control Centre, train detection and points. Possessions management and ESR/TSR speed restriction arrangement based on hand held terminals. A high number of different level crossing equipment will be kept though.
Project Timeline	July 2005-December 2011
Project Status	In full commercial operation since 2011. Onboard fitment delayed programme as insufficient spare trains were available and project experienced lacking capability of onboard fitment contractor.
Project Baselines	SRS 2.3.0. Upgrade to 2.3.0d is being assessed at the moment.
Measures re. capacity	Block optimisation at Machynellth to enable 3 minutes headway.
Measures re. ERTMS baselines	None.

Project Aspect	*Statement*
Project comments on readiness	ETCS Level 2 application on lines with level crossings, and ETCS Level 2 application on simple lines and simple junctions, mixed traffic and ETCS Level 2 application on simple stations can be set to readiness level 9 based on this project.
#11	**Germany: Berlin-Halle/Leipzig**
Perimeter	Berlin-Halle/Leipzig, 160 km
Line categorisation	Double track upgraded line 200 km/h ETCS level 2 with lineside signals (Mixed signalling), fall back to LZB/PZB.
Operational characteristics	High capacity, up to 200 km/h, Mixed traffic
Comparison to Danish network	Incomparable operational characteristics, very complex technical layout due to overlaying design. Line partially comparable to København-Ringsted
Rolling Stock	1 DMU for testing
Interlocking	20 Interlockings, 3 RBC's, 1045 balises
Scope	First part build as European test line, second part added as commercial operation. ERTMS level 2 on top of existing Interlocking and LZB centrals.
Project Timeline	1999 – 2005
Project Status	Being upgraded to SRS 2.3.0d. Will start full scale ETCS operation as part of the Berlin-Nürnberg corridor (see separate sheet on VDE8 project)
Project Baselines	SRS 2.2.2.
Measures re. capacity	N/A
Measures re. ERTMS baselines	None.
Project comments on readiness	ETCS Level 2 application on simple lines and simple junctions, mixed traffic as well as simple stations, and ETCS Level 2 application on lines with conventional signalling can be set to readiness level 9 based on this project.

Project Aspect	*Statement*
#12	**Luxembourg: Network**
Perimeter	Bettembourg frontiere-Luxembourg (16,7 km double track 140 km/h) Luxembourg-Ettelbruck (30,5 km mostly double track 120 km/h) Ettelbruck – Diekirch (4,1 km single track max 80 km/h) Ettelbruck - Bissen (8,7 km single track max 45 km/h) currently in operation (60 km line) Total 270 km line, to be fitted.
Line categorisation	Double track and single track with passing loops, core network 100-140 km/h, secondary lines 45-80 km/h ETCS level 1 with lineside signals.
Operational characteristics	Low-Medium density, Mixed traffic
Comparison to Danish network	Lines comparable to Svendborgbanen, Grenåbanen and Aarhus-Langå-Aalborg
Rolling Stock	Approx. 110 vehicles, approx. 20 yellow fleet
Interlocking	Currently around 300 balises and associated LEU's.
Scope	Network application of ERTMS level 1 for Safety and Interoperability
Project Timeline	2000-2013
Project Status	In commercial operation
Project Baselines	SRS 2.2.2 being upgraded to 2.3.0.
Measures re. capacity	N/A
Measures re. ERTMS baselines	N/A
Project comments on readiness	ETCS Level 1 application with lineside signals and simple junctions and stations ETCS Level 1 application on medium and large stations Can be set at readiness level 8 based on this project. When the remaining parts of the network enter full operation, project will indicate SRL 9.
#13	**Italy: Roma-Napoli**
Perimeter	Roma-Napoli, 204 km
Line categorisation	High speed 350 km/h ETCS level 2 without lineside signals.
Operational characteristics	HSL, Mixed traffic, 2½ minute headway at 350 km/h

Project Aspect	*Statement*
Comparison to Danish network	None, but general system aspects are valid
Rolling Stock	27 EMU (ETR 500)
Interlocking	18 interlockings, 3 RBCs, 1500 balises and 60 LEU's
Scope	Built with ERTMS level 2, for Safety at high speed
Project Timeline	2001-2005
Project Status	In commercial operation since 2005.
Project Baselines	SRS 2.2.2c. Upgrade to 2.3.0d (trackside) until 2015[3]
Measures re. capacity	N/A
Measures re. ERTMS baselines	N/A
Project comments on readiness	ETCS Level 2 application for simple lines and simple junctions, uniform traffic and simple stations can be set at readiness level 9 based on this project.
#14	**Spain: Madrid-Barcelona**
Perimeter	Madrid – Barcelona, 651 km
Line categorisation	High speed 300 km/h (planned 350 km/h when Level 2 commissioned) ETCS level 2 without lineside signals, fall-back to ETCS level 1 with lineside signals. Mixed signalling.
Operational characteristics	Double track, High speed line, uniform traffic
Comparison to Danish network	None, but general system aspects are valid
Rolling Stock	52 EMU, 4 loco
Interlocking	15 interlockings and 1500 track circuits, 9 RBCs, and 3500 balises
Scope	Built with ERTMS level 1 and 2, for Safety at high speed
Project Timeline	1997-2008
Project Status	Commercial operation on ETCS level 1, ETCS level 2 in commercial operation on majority of the line, remaining parts being commissioned. First ETCS L1 operations on 50% of the line started in 2003.
Project Baselines	SRS 2.2.2c subset considered compliant to SRS 2.3.0.

[3] Note: other Italian lines reportedly have performed SRS 2.3.0d upgrades in 2009-2012

Project Aspect	*Statement*
Measures re. capacity	Short blocks for ETCS level 2
Measures re. ERTMS baselines	None
Project comments on readiness	ETCS Level 1 application with lineside signals and simple junctions and stations can be set at readiness level 9 based on this project. ETCS Level 2 application on simple lines and simple junctions, uniform traffic as well as simple stations can be set at readiness level 9 based on this project.
#15	**Sweden: ERTMS Regional**
Perimeter	Repbäcken - Malung, 134 km
Line categorisation	Rural, Single track with passing loops ETCS level 3/Regional without lineside signals.
Operational characteristics	Low density, Mixed traffic
Comparison to Danish network	Line comparable to Struer-Thisted and Bramming-Tønder
Rolling Stock	N/A
Interlocking	5 stations, 33 Level crossings. Future 1 TCC (RBC+IL)
Scope	Re-signalling. Pilot for ERTMS Regional concept (ETCS level 3), in total more than 1000 km roll-out planned between 2009 and 2014.
Project Timeline	2005-2010
Project Status	Early deployment operation
Project Baselines	Onboard SRS 2.3.0 + Infrastructure ERTMS Regional FRS 3.0.
Measures re. capacity	None, low capacity demand.
Measures re. ERTMS baselines	Development contract for verification of the ERTMS Regional system requirements specification, upgrades integrated in contract.
Project comments on readiness	ETCS Level 3/Regional application on rural lines, with and without train coupling/splitting can be set at readiness level 5/6 based on this project. This project also contains the element Evolution of ERTMS technology: Merger of interlocking and RBC, also at readiness level 5/6. The SRL will rise to 9 when the deployment on following lines are started.
#16	**Sweden: Botniabanen and Ådal Line**
Perimeter	Sundsvall - Kramfors (=Ådal Line, 130 km), and Kramfors/Nyland – Örnskoldsvik - Umeå (Botnia, 190 km)

Project Aspect	*Statement*
Line categorisation	New built line 250 km/h, Single track with passing loops ETCS level 2 without lineside signals. ca. 40 level crossings managed by ERTMS
Operational characteristics	Medium density, Mixed traffic, 14 stations
Comparison to Danish network	Line somewhat comparable to Vejle – Holstebro – Struer Handling of level crossings
Rolling Stock	(unknown amount)
Interlocking	22 interlockings
Scope	First commercial ETCS level 2 project in Sweden with extension southwards. Most of line is new built, while 100km of Ådal line was migrated.
Project Timeline	1999-2011
Project Status	In commercial operation
Project Baselines	SRS 2.3.0d
Measures re. capacity	Long passing loops
Measures re. ERTMS baselines	N/A
Project comments on readiness	ETCS Level 2 application on simple lines and simple junctions, mixed traffic as well as simple stations can be set at 9 based on this project
#17	**France: LGV-Est (Corridor POS and 2007)**
Perimeter	(Paris) - Baudrecourt, 300 km
Line categorisation	High speed 350 km/h ETCS level 2 without lineside signals (being commissioned), double equipped with TVM430 and lineside signals. Mixed signalling.
Operational characteristics	Double track, High speed line, uniform traffic
Comparison to Danish network	None, but general system aspects are valid
Rolling Stock	19 EMU
Interlocking	N/A
Scope	Built with ERTMS level 2 and TVM430
Project Timeline	1997-2013

Project Aspect	*Statement*
Project Status	Commercial operation on TVM430, ETCS level 2 planned to be commissioned by end of 2013.
Project Baselines	SRS 2.2.2 with corridor addition from Subset 108 1.1.0 considered compliant to SRS 2.3.0. Upgrade to 2.3.0d is being assessed at the moment.
Measures re. capacity	N/A
Measures re. ERTMS baselines	None
Project comments on readiness	ETCS Level 2 application on simple lines and simple junctions, uniform traffic as well as simple stations can be set at readiness level 7/8 based on this project. ETCS Level 2 and GSM-R-end-to end interface at a state border can be set at readiness level 7 based on the overarching project POS Corridor.
#18	**Belgium: HSL L3 & L4 (Corridor 2007)**
Perimeter	L3: Liege – German border L4: Antwerp – Dutch border, 30 km
Line categorisation	High speed 300 km/h ETCS level 2, fall back and mixed operation ETCS level 1 and lineside signals. Mixed signalling.
Operational characteristics	Double track, High speed line, uniform traffic
Comparison to Danish network	None, but general system aspects are valid
Rolling Stock	N/A
Interlocking	N/A
Scope	Built with ERTMS level 2 and 1
Project Timeline	1997-2008
Project Status	In commercial operation.
Project Baselines	SRS 2.2.2 with corridor addition from Subset 108 1.1.0 considered compliant to SRS 2.3.0. Upgrade to 2.3.0d is being assessed at the moment.
Measures re. capacity	N/A
Measures re. ERTMS baselines	None

Project Aspect	*Statement*
Project comments on readiness	ETCS Level 2 application on simple lines and simple junctions, uniform traffic as well as simple stations can be set at readiness level 9 based on this project. ETCS Level 2 and GSM-R-end-to end interface at a state border can be set at readiness level 9 based on the overarching project Corridor 2007 and the physical border between L4 and Dutch HSL South.
#19 (new)	**Germany: German Unification Transport Project 8 (VDE8)**
Perimeter	Nürnberg - Berlin, approximately 400 km
Line categorisation	VDE 8.1: Nürnberg - Ebensfeld, upgrade existing line 83 km VDE 8.1: Ebensfeld - Erfurt, new line 107 km VDE 8.2: Erfurt - Halle/Leipzig, new line 23 km VDE 8.3: Leipzig/Halle - Berlin, upgrade of line 187 km plus their integration with new nodes Erfurt and Leipzig
Operational characteristics	Higher network capacity, reduced travel time (goal: Munich - Berlin in less than 4 hours) Mix of high-speed (300 km/h) passenger and cargo traffic. New Level 2 lines to be deployed without line-side signalling and fall-back.
Comparison to Danish network	Copenhagen – Ringsted
Rolling Stock	N/A
Interlocking	6 ESTW - UZ
Scope	A classical infrastructure project (new tunnels, bridges, buildings) funded by TEN-T Nr 1 (Berlin - Brenner - Verona/Bologna - Palermo)
Project Timeline	VDE 8.1: until 2017 VDE 8.2: until 2015 VDE 8.3: 2006 (see reference #11)
Project Status	Tendering completed (Siemens and Kapsch)
Project Baselines	- VDE 8.1: Baseline 3 - VDE 8.2: initially SRS 2.3.0d with option for upgrade for Baseline 3 - VDE 8.3: which is being upgraded to SRS 2.3.0d
Measures re. capacity	Construction of new lines and upgrade of existing lines is the biggest contributor to additional capacity.
Measures re. ERTMS baselines	N/A
Project comments on readiness	Under construction, therefore SRL 2.

Project Aspect	*Statement*
#20 (new)	**Germany: Berlin - Rostock**
Perimeter	Berlin - Rostock, approx. 200 km
Line categorisation	Existing line being upgraded for higher speeds (from 120 to 160 km/h; Berlin - Rostock in less than 2 hours). Connects port of Rostock to TEN-T corridor in Berlin.
Operational characteristics	Conventional rail; mix of passenger and cargo trains.
Comparison to Danish network	
Rolling Stock	N/A
Interlocking	13 interlockings
Scope	Overlay of PZB on existing line with ETCS Level 2[4]
Project Timeline	2011 - 2013
Project Status	Track tests ongoing (Q1/2013) Commissioning planned for end of 2013
Project Baselines	SRS 2.3.0d
Measures re. capacity	
Measures re. ERTMS baselines	Baseline 3[5]
Project comments on readiness	Tests ongoing, operational end of 2013. ETCS Level 2 application on lines with conventional signalling can be set to readiness level 4-6 based on this project.
#21 (new)	**Belgium: 1'900 km of Level 2 lines**
Perimeter	Renewal of a number of lines throughout the country, which to be complemented with ETCS Level 2
Line categorisation	Conventional rail traffic, safety and capacity upgrade keep most existing interlockings
Operational characteristics	Mixed traffic, mixed densities ETCS Level 2 in overlay with national system TBL1+

[4] to be confirmed

[5] Tendering in 2011 targeted to implement Baseline 3 but a confirmation for this was not received yet

Project Aspect	*Statement*
Comparison to Danish network	Not comparable as Denmark replaces all existing interlocking and does have no overlay with national system
Rolling Stock	N/A (ETCS is compulsory from 2025 on)
Interlocking	Approximately 5,000 signals
Scope	ETCS Level 2 deployment part of Infrabel's overall ETCS strategy, which to have the entire railway be protected by ETCS by 2025.
Project Timeline	2012 - 2022: pilot line planned in 2014/2015, succeeded by rollout phases
Project Status	Final phase of tendering (BAFO; Q3/2013)
Project Baselines	ERTMS Baseline 3, ETCS Level 2
Measures re. capacity	Focus of this project is safety, punctuality.
Measures re. ERTMS baselines	Baseline 3 as the common basis for all the trains of tomorrow.
Project comments on readiness	This activity is still in the tendering phases. It does however introduce broad coverage on conventional rail including stations.
#22 (new)	**Spain: Madrid Commuter Lines**
Perimeter	Chamartin - Sol - Atocha (Madrid metropolitan area), 9 km / 160 km
Line categorisation	Deployment of ETCS Level 2 in Chamartin and Atocha stations and the tunnel in-between. Long-term intention is to deploy Level 2 on several sections of the Commuter Lines (beyond line C4 which is ETCS Level 1 already)
Operational characteristics	Commuter traffic in tunnel connecting Chamartin and Atocha stations Overlay of ASFA (national system) with ETCS Levels 1 and 2.
Comparison to Danish network	N/A
Rolling Stock	Approximately 220 commuter trains, all SRS 2.3.0d, already equipped
Interlocking	Existing interlocking not touched
Scope	Check of reliability of ETCS Level 2 in dense traffic
Project Timeline	2011 - 2014 for L2 in tunnel further L2 deployment on commuter network is unclear
Project Status	Laboratory testing (Q3/2013) Track testing in winter 2013/14
Project Baselines	SRS 2.3.0d

Project Aspect	*Statement*
Measures re. capacity	Slightly increased capacity is expected due to Level 2 infill.
Measures re. ERTMS baselines	SRS 2.3.0d is the (only) Spanish reference so far
Project comments on readiness	Applies ETCS in complex stations to a certain extent but with limited scope: commuter trains will transit through Level 2 area (i.e. are not supposed to perform change of direction, splitting or joining within Level 2 etc.)
#23 (new)	**Switzerland: Lausanne - Brig (Lake Geneva area)**
Perimeter	Approx. 150 km split into several segments for ETCS Level 2: a) Pully - Villeneuve, b) Roche - Bex, c) Les Paluds - Vernayaz, d) Sion - Sierre, e) Salgesch - Leuk, f) Visp - Simplon Intermediate segments based on Level 1 LS: g) Martigny - Ardon, h) Turtmann - Raron
Line categorisation	Conventional rail with small to medium stations
Operational characteristics	Mixed conventional traffic (passenger & cargo), partly lying on Corridor A
Comparison to Danish network	Semi-rural line with small to medium stations and need for joining splitting change of direction
Rolling Stock	N/A
Interlocking	21 (among 28) to be replaced
Scope	This is the first deployment of ETCS Level 2 on existing lines in Switzerland triggered by renewals of interlockings due to extension & automation of operations (change direction, splitting).
Project Timeline	2010 - 2020 with commissioning dates: - L2: a) 2015, b) 2019, c) 2020, d) 2016, e) 2020, f) 2020 - L1LS: g) & h) 2017
Project Status	Implementation design
Project Baselines	SRS 2.3.0d for all projects with commissioning up to 2017; Baseline 3 planned for projects with later commissioning date
Measures re. capacity	Increased traffic volumes requires not only more suitable train control but also refined procedures for train handling on interlocking an TMS levels
Measures re. ERTMS baselines	SRS 2.3.0d remains to be the reference for ETCS Level 2 deployment (except for L1LS which requires Baseline 3), and no formal decision on specific date has been made yet, from which on Baseline 3 would be the reference for Level 2 projects.

Project Aspect	*Statement*
Project comments on readiness	Introduction of ETCS Level Baseline 3 by occasion of required renewal of interlocking, including small stations. ETCS Level 2 / L1LS application can be set to readiness level 2-3 based on this project.
#24 (new)	**Norway: Østfoldbanen Test Line**
Perimeter	Ski to Sarpsborg on eastern route (southeast of Norway)
Line categorisation	Single track
Operational characteristics	Freight and passenger (regional) traffic
Comparison to Danish network	Early deployment line
Rolling Stock	N/A
Interlocking	
Scope	Pilot line
Project Timeline	2011 - 2014
Project Status	
Project Baselines	SRS 2.3.0d
Measures re. capacity	
Measures re. ERTMS baselines	
Project comments on readiness	ETCS application can be set to readiness level 2 based on this project.
#25 (new)	**The Netherlands: ETCS Level 3 Pilot[6]**
Perimeter	
Line categorisation	
Operational characteristics	
Comparison to Danish network	
Rolling Stock	
Interlocking	

[6] major data missing yet - nevertheless included to capture impact on overall ERTMS maturity

Project Aspect	*Statement*
Scope	
Project Timeline	2013
Project Status	Tests ongoing or just completed (07/2013)
Project Baselines	SRS 2.3.0d
Measures re. capacity	
Measures re. ERTMS baselines	
Project comments on readiness	This pilot shows that ETCS Level 3 is feasible. ETCS application can be set to readiness level 3-5 based on this project.
#26 (new)	**Denmark: Signalling Programme**[7]
Perimeter	Entire Fjernbane Railway Network (which excludes S-Bane)
Line categorisation	Mixed passenger and railway traffic, rural lines as well as big stations
Operational characteristics	Target solution: ETCS Level 2 without fall-back nor any overlay Migration period (2017 - 2022) with Danish STM.
Comparison to Danish network	N/A
Rolling Stock	600-700 vehicles to be retrofitted (EMU, DMU, E-Locos, D-locos and trailers, yellow fleet)
Interlocking	All to be renewed
Scope	Renewal of entire signalling infrastructure and TMS for an highly industrialised production of train operation
Project Timeline	2009 - 2022
Project Status	Preliminary design phase
Project Baselines	Baseline 3, SRS 3.3.0 plus ETCS over GPRS as targeted for second maintenance release of B3 and Online KMS
Measures re. capacity	Year 2020 timetable to foresee double traffic
Measures re. ERTMS baselines	Fjernbane Railway is Baseline 3, but the border to Sweden (Øresund bridge) will lead to SRS 2.3.0d. It is required that both Swedish SRS 2.3.0d trains and Danish Baseline 3 trains shall be able to operate on the Swedish ETCS lines.

[7] included to capture impact on overall ERTMS maturity in tables further below

Project Aspect	*Statement*
Project comments on readiness	Due to the status of the project the SRL is 2.

3.4 Evaluation of the Technical Maturity of ERTMS

The following table contains an overview of the assessments of the projects covered in chapter 3.

Maturity Aspects / **ERTMS Project**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	**S**	**T**	**U**
1							9														
2	9		9																		
3					9	9															
4							3	3													
5							9	9													
6								1	0												
7				8-9											3-4				4		
8					9																
9					9																
10						9	9			2-3											
11						9	9				9										
12	8		8																		
13					9		9														
14	9				9		9														
15													5					5			
16						8	8														
17					7-8		7					7									
18					9		9					9									
19						2	2	2											2		
20						4-6	4-6														
21						1	1	1							1	1	1		1		
22									2-3								2				
23						2-3	2-3	2-3								2-3					
24						2	2														
25													5	3-4				5			
26								2	2	2						2	2		2	1-2	
Highest maturity rating achieved for this aspect	**9**	**-**	**9**	**4-5**	**9**	**9**	**9**	**4**	**2-3**	**2-3**	**9**	**9**	**5**	**3-4**	**3-4**	**2**	**1-2**	**5**	**4**	**1-2**	

3.5 Results

3.5.1 *System readiness results*

Based on the considerations in above-listed projects, ERTMS maturity today is evaluated as follows, and compared to the initial maturity study from 2008:

ID	Readiness Aspect	2008	2013
A	ETCS Level 1 application with lineside signals and simple junctions and stations	9	9
B	ETCS Level 1 application in pure cab-signalling mode	0	0
C	ETCS Level 1 application on medium and large stations	9	9
D	ETCS Level 1 Limited Supervision	1	4 - 5
E	ETCS Level 2 application on simple lines and simple junctions, uniform traffic	9	9
F	ETCS Level 2 application on simple lines and simple junctions, mixed traffic	9	9
G	ETCS Level 2 application on simple stations with and without shunting mode	9	9
H	ETCS Level 2 application on medium stations with and without shunting mode	1	3
I	ETCS Level 2 application on large nodes with and without shunting mode	0	2-3
J	ETCS Level 2 application on lines with level crossings	2	2-3
K	ETCS Level 2 application on lines with conventional signalling	9	9
L	ETCS Level 2 and GSM-R-end-to end interface at a state border	7	9
M	ETCS Level 3/Regional on rural lines, with and without train coupling/splitting	2	5
N	ETCS Level 3 application on main lines with and without junctions/stations	0	3 - 4
O	Evolution of ERTMS technology: Unified braking model	3	3 - 4
P	Evolution of ERTMS technology: Cold movement detection/Start of Mission	1	2
Q	Evolution of ERTMS technology: GSM-R for dense traffic	0-1	1 - 2
R	Evolution of ERTMS technology: Merger of interlocking and RBC	1	5
S	Evolution of ERTMS technology: Availability of spec. and products for baseline 3	-	4
T	ETCS Level 2/3 application with Key Management System (KMS) complemented by online and PKI secured update of keys.	-	1 - 2
U	ETCS Level 2 application on lines and/or stations for the purpose of increasing network capacity	-	-

Definition of SRL (repeated from chapter 3.2.2):

Level	Definition
0	No agreed project specific specification available
1	Agreed project specific specification available, no product development work undertaken
2	Product development work ongoing
3	Laboratory tests ongoing
4	Test operation ongoing
5	Early deployment* being implemented
6	Early deployment* operation going on successfully

Level	Definition
7	Productive system** being implemented
8	Restricted productive operation** going on
9	Full productive operation** going on successfully

Notes:
* *An early deployment is a project aiming at resolving teething troubles and getting familiar with the ETCS operation. In such a project, a certain level of troubles is accepted.*
** *A productive system or a productive operation is a project aiming at a trouble-free operation under full load, which is expected to run smoothly from day one.*

3.5.2 *ERTMS Maturity Conclusion*

From the assessments in chapter 3.3 and 3.4 it can be seen that:

- ETCS performs perfectly on lines but it takes time to bring it to the stations;
- ETCS has grown up, fall-backs are not required;
- ETCS is gaining popularity - deserves exclusive deployment (no overlay).

Further, the following conclusions can be made:

ERTMS Achievements
The following achievements have been realised:

- Products have matured, high availability and reliability of products
- Technical, cross-supplier / product interoperability is realised
- ETCS Level 1: Operation on lines and in complex station, with or without overlay of national system is possible
- ETCS Level 2: Operation on lines and in small stations is possible
- ETCS Level 3: Feasibility tests are ongoing

Challenges to ERTMS
ERTMS faces the following challenges in order to become a proficient commodity:

- ETCS Level 2/3: Operational Procedures in stations to be implemented, Start of Mission (SoM) functionality to be enhanced.
- Train operation to be based on the current available ETCS functionality (avoid nationalisation of operational rules).
- Use of GPRS for packet-switched ETCS (RBC to Onboard communication): Development of a unified (standardised) solution
- Interoperability: Application of standard testing and approval processes and adoption across Europe.
  - for Rolling Stock, one single certification per OBU
  - for trackside, one single OBU for testing and commissioning
- A widespread and scalable Key Management System (KMS), complemented with automation of key exchange (based on online and PKI exchange capabilities). Flexibility to manage a very large number of keys - throughout their entire life cycle
- ETCS and Interlocking products to become more integrated for the purpose of fully exploiting the available factual information from wayside, with the effect of lesser engineering costs and higher train operation performance.
  This especially in view of ETCS Level 3 applications with moving blocks.

Remaining Constraints with ERTMS
The following constraints require further attention:

- Braking Curves: Gaps between speed supervision (= assumed brake performance) and real braking performance of the trains to be minimised (avoid national values).

- ETCS alone does provide features for increase of capacity. Gains to be achieved only in collaboration with optimised track layouts, advanced interlocking functionality, and advanced traffic management systems featuring automation, also in degraded situations (e.g. auto re-scheduling of trains and routes).
- True bearer-independence: Track-Train communication (RBC – OBU) to become independent from the telecom media (only IP as common denominator).
- Inherited operational processes: ETCS is not designed to emulate all legacy systems and inherited operational processes.

Many projects are currently in the design and lab testing phase, and a substantial gain on experience on the more complex applications can be expected within the next 3-5 years. For larger station areas the limited GSM-R data capacity can be a hindrance. Copenhagen Central Station will be a special challenge in this aspect.

The issue of GSM-R capacity has been assessed. It seems that a solution based on current standards (circuit switched data) could just meet the requirements even for the dense areas around Copenhagen. However, an upgrade to packet switched data is deemed indispensable in order to reduce bandwidth consumption and to leave some capacity to voice radio applications.

3.5.3 *Readiness of ETCS SRS 2.3.0*

The readiness of first ERTMS baseline (2.3.0) is proven by numerous projects that have been carried out successfully in Europe during the past 5 to 10 years. The restrictions explained in the first edition of this ERTMS maturity study are still valid.

As the former baseline 2.3.0d has been superseded by Baseline 3 in 2012 new ERTMS onboard projects must use Baseline 3 as the contract reference in order to deliver Interoperable products. Infrastructure projects still have the choice to implement on the basis of 2.3.0d or Baseline 3 depending on the need for functionality. For infrastructure projects it is highly recommended to use system version 1.1 instead of 1.0 if a „B2 only" functionality is pursued, as this version includes corrections and improvements.
Trackside projects should be able to design a baseline 3 implementation by using SRS 2.3.2 functions uniquely, allowing both SRS 2.3.0d trains and Baseline 3 trains to operate on it (see measures on baselines in project #26).

There are doubts whether the declared backward compatibility between Baseline 3 and SRS 2.3.0d will hold in practice. An ongoing compatibility analysis which is expected to be completed in 2013 will provide clarifications to this issue.

3.5.4 *Readiness of ETCS SRS 3*

ERTMS Baseline 3 has formally been released in a TSI update in 2012. It thus forms the mandatory reference for new ERTMS deployment projects. ETCS is now moving from high-speed lines to conventional rail networks. Fully implemented products are expected to be available in 2014 (factory tested).

ERTMS Baseline 3 contains achievements as well as issues pending resolution in future maintenance updates, such as:

- Subset-026, the system requirement specification for ETCS is included in version 3.3, and is a major reference for implementation in Denmark.
- ERTMS Baseline 3 specifies backward-compatibility with Baseline 2 lines, theoretically allowing Baseline 3 equipped trains to operate on lines that were deployed with ETCS SRS 2.3.0d. In practise however, a significant number of issues have in the meanwhile been detected. They require resolution in order to proceed with the implementation of Baseline 3.
- Subset-039 for RBC/RBC handovers is not yet aligned with the (new) set of features of Baseline 3 (namely subset-026). There is a stable technical draft of this document, which is used as reference for the Danish infrastructure projects, in particular for the border

between Fjernbane East and West, which is a cross-supplier RBC/RBC handover location (Alstom and Thales).

ERTMS Baseline 3 is now entering a phase of practical consolidation and maturing by early adopter projects. A number of such projects have initiated and are currently in tendering or design phases mostly. The industry expects to deliver first fully implemented onboard systems in around 2014.

It is expected that these projects will report issues and feedbacks on the specifications once they shall enter testing and trialling of the required Baseline 3 functionality, performance, robustness and not least Interoperability. However, based on the experience gained in the past projects, it is assumed that the Baseline 3 products will converge faster towards performing and interoperable solutions than was the case for baseline 2 implementations. For this purpose, a timely available maintenance release of Baseline 3 is required to encompass the vast majority of issues on the specifications that have been identified so far already.

The identification and resolution of issues will cause difficulties for projects during their progress:

- If a specific issue turns out to be relevant for a project, it should know how it will be resolved in a future Baseline release (no matter when this will happen). The aim is to protect the investments made, because the change request can be implemented as part of a planned product development and be part of the next maintenance release.
- If a specific change request turns out to be irrelevant for a project (e.g. because the infrastructure does not make use of the particular functionality), there is no need for a new maintenance release. Thus, additional costs can be avoided.
  In the worst case, several maintenance releases will appear in short intervals during the project's duration.

Projects therefore prefer to negotiate and decide with their suppliers on a CR basis, based on their individual project priorities. A precondition for this is that ERA will publish all completed resolutions on error CRs as soon as possible, even if simply in a "SRS Corrigenda" on their website.

3.5.5 *openETCS*

The purpose of the openETCS project is to leverage the cost-efficient and reliable implementation of ETCS. The related business concept is aimed to significantly cut the costs of the onboard product to or even below conventional high-performance cab signalling systems (TVM, LZB). For this an integrated modelling, development, validation and testing framework is going to be developed (based on EVC kernel Baseline 3).
openETCS focuses on an open-source version of the heart of the signalling software that will allow a lot of developers to monitor the code and check for any bad implementation.
openETCS uses formal proof to ensure safety definitively. By making the core functionality software fully transparent, it will open up the market for software services in equipment that tends to last between 20 and 40 years.
The project consortium driving forward this project under the head of ITEA consists of 35 companies from various countries including the Netherlands.
Project start was in 2012 and in 2016 the formal ETCS on-board specification, tools chain, and non-vital OBU reference unit should be available for download.
The first demonstrators consisting of

- the EVC kernel
- the on-board peripheral equipment connected to the EVC, and
- the test environment simulating the driver, train movement and track transmission

are already available (ERSA).
To commercially back-up the initiative contracts will be based on the EUPL (European Union Public License) contract terms. The main goal is on being consistent with the copyright law in the 27 Member States of the European Union, while retaining compatibility with popular open-source software licenses.
First tenders have already been placed in the market based on this open-source software license regulation (Service Level Agreements).

- The first is for 75 ICE-T trains for the Austrian railways (Westbahn).
- The second for 50 ICE3 trains for the Deutsche Bahn.

So a total of 250 ETCS on-board equipment (Baseline 3) will be purchased based on open-source software license agreements.
The contract conditions include the provision of the open source software latest on 31.12.2016.
The works on openETCS are advancing (about 30% of the works completed) and in 2016 to works should be finalized. .
In order to meet the time schedule testing of openETCS will start in 2015. Validation of the software is due in 2016.
At this time the EVC-kernel onboard peripheral equipment connected to the EVC and test environments should be available.

3.6 Other aspects

3.6.1 *Effects of ETCS on Capacity*

Utilisation of ETCS alone influences the overall capacity only to a limited extent. Considerable capacity gains can be achieved by use of ETCS in combination with its neighbour systems.

Deployment of ETCS on existing infrastructures will yield in less capacity if applied to unchanged conditions such as:

- block sections not being optimised
- overlay and/or fall-back with existing train control system
- remaining operational procedures as used for the previous systems

By removal of these constraints utilisation of ETCS can lead to a higher capacity

The following related opportunities may contribute to higher capacity. However, it is recommended that they are further analysed:

- Train management System utilising the trains' position location reports provided by ETCS (locations and current speeds);
- Optimisation of signalling layout in case that interlocking will be expanded as well;
- Operational rules suitable for the new ERTMS system, leaving legacy systems behind;
- New product generations processing all data available. For axle counters benefit would be improved movement authority management at start of mission.

3.6.2 *Impacts on Migration Planning*

Several projects, including #6 (Large nodes project), #10 (Cambrian), #5 (Gotthard) and #26 (Signalling Programme Denmark) have or will be introducing the complex operational elements at more or less the same time (except Cambrian). Benefits will be realised through cooperation with the related project teams. A full operation reliability growth period of at least 1½ years should be planned for handling teething issues with technology as well as operational rules.

In order to guarantee smooth reliable operation of the system and interaction with the drivers/operators all main operational scenarios must be thoroughly tested at early deployment lines. This is needed in order to mature the new operational rules. The first lines and training simulators shall be used for training of operators and drivers in order to prepare the subsequent rollout on dense traffic corridors.

In order to facilitate the infrastructure rollout and keep the flexibility of rolling stock usage, rolling stock fitment should be carried out as early and fast as possible following the completion of the early deployment lines. This will also help the drivers getting accustomed with the DMI of the new system while running on ATC lines (STM operation).

3.6.3 *Impacts on GSM-R Capacity*

Future ERTMS Level 2 projects such as #6 (Large nodes) and #26 (DK Signalling Programme) will encompass large nodes must prove the use of GSM-R based data communication for large nodes. The capacity at large nodes will be limited by GSM-R data communication capacity as long as this is based on circuit switched data and ISDN protocol. This issue is addressed in the above mentioned projects as well as other projects.

A solution based on packet switched data and IP protocol is being developed and tested in labs. However, still no draft specifications are available.

3.6.4 *Impacts of Overlay of ETCS with national Train Control*

Overlaying ETCS Level 2/3 with a national train control system will always require some compromises regarding operational issues, capacity, reliability, etc. which may later turn out to have a more substantial impact than assumed initially.

An in-depth analysis depends of the specific application (country, network) and is regarded outside the scope of this report.

3.6.5 *Braking Curves harmonised in Baseline 3*

Baseline 3 will include standardised braking curves for the benefit of interoperability. This harmonisation will reduce performance even though the braking curve shapes can be fine-tuned by the use of ETCS National Values. The impact is:

- There is a tendency to flatter the supervision curves more than adequate (in comparison to legacy train control-specific braking curves);
- ETCS defines more level of indicators /warnings (i.e. before an brake intervention by the system will occur) than most of the legacy train control systems.

This development calls for strategic decisions which include but are not limited to:

- Whether to align the braking curves to the ones of the previous national train control system (= comparison of stopping points) which leads to much leaner Verification and Validation process of each train's braking capabilities, or to align to factual safe braking capabilities of each train individually.
- Whether to drop application of service brake;
- Whether to letting the drivers run in the yellow warning indication curve.

A balance needs to be struck between making the system too conservative resulting in being difficult to drive/poor performance or too aggressive resulting in frequent SPADs.

3.6.6 *Key Management System Scalability Issue*

Extensive deployments of ETCS will foster the fitting of ETCS equipped trains significantly in the mid- and long-term. The increasing amount of trains operating in ETCS equipped areas need to be managed for their crypto keys, which is compulsory for ETCS Level 2 operation.

The current ETCS standards based on manual transmittal and symmetrical keys for peer authentication calls for two enhancements on top of the existing offline protocols, currently supported by key management system concepts:

- Online and automated distribution of keys to any involved ETCS devices (RBCs, EVCs) at any point of time and interval in order not to be bothered by long outages and complications caused in e.g. peering organisations;
- Adopt PKI-based encryption principles for exchanging keys in order to significantly reduce the potential for compromising keys while they are being distributed. This will compensate the safety and security issues.

Drivers, DMI and Human Factors

The ETCS Driver Machine Interface (DMI) went through an exhaustive human factors process and a 'standard' DMI has been defined. Some railway organisations prefer to customise the physical and graphical layout whilst others have stayed with the standard. It is recommended to implement a standard DMI.

A human factors study will be required as part of the consultative process.

3.6.7 *Adaptability of current ERTMS Products*

In contrast to an onboard system whose behaviour is defined to remain generic everywhere, trackside projects often need to fine-tune their interlockings and train control systems in compliance with the operational needs and processes of the specific railway. Some products, RBC, Interlockings (IXL) etc. are able to adopt specific functionality by configuration or by enhancing their software. Others are less adaptable (typically inherited relay-related logic and available digital products) and it is thus difficult to implement some more sophisticated custom specific features.

It is advised to consult the advertised products against flexibility for customer-specific adaptations.

3.6.8 *Impacts on Maintenance*

ETCS trackside equipment requires little preventive maintenance, but an investigation needs to be made of potential damage to EuroBalises, loops and tail cables from track vehicles. The ETCS onboard equipment requires little preventive maintenance apart from visual inspection for damage to equipment installed on the underside of the train that is part of the normal daily pre-start inspection. The ETCS trackside sub-system should not cause any concern for signalling maintenance staff already familiar with e.g. computer-based interlocking. The ETCS on-board sub-system may be more of an issue where it is retrofitted to old rolling stock as it involves putting complicated electronic/computerised equipment on board trains that were previously relatively low-technology. This may require additional training of rolling stock maintainers.

3.7 Recommendations

In order to prepare the large scale signalling renewal projects a number of issues need addressing:

1. Development of specification and scenarios for complex station processes in a joint industry team including suppliers. Make full scale test on early deployment schemes. Cooperate with other European projects with same needs, and include full package in the contract scope.

2. Plan for a full operation reliability growth period of at least 1.5 year on early deployment schemes in order to reduce the risk of malfunctioning systems and operational disturbances on the following lines. Use the time available for continuous broadening of ETCS-related operational knowhow across all involved personnel and organisations.

3. Avoid overlays with national systems for multi-mode operation as well as fall backs as much as possible as the development efforts and potentially resulting long-term constraints will out-weight the benefits.

4. Test and optimise operational scenarios in cooperation with drivers and train controllers in order to actually realise a system meeting the performance requirements. Use test labs as well as software simulators, mock-ups and other agile development methods.

5. When fitting existing lines, optimise methods for switching between old and new control of objects in cooperation with suppliers in order to enable shadow running of the new systems during the taking in service period.

6. Consider parallel development activities for large nodes, ERTMS regional and other issues with low system readiness. Include feedback from other European countries in parallel design on conventional lines and stations.

7. Include measures to enable efficient and cost effective upgrade of systems. The introduction of new ERTMS baselines and interfaces (e.g. GSM-R GPRS/IP) will happen during migration as well as operation and handling must be included in supplier contracts. Define processes for handling and coordinated introduction of upgrades into your network and/or fleets, to be suitable to upgrades with big or small changes irrespective of their interval of appearance.

8. Exercise special attention to the critical design topics such as:
   - parameterisation of the braking curves
   - compatibility issues between trackside and/or onboard systems using different ETCS baselines (SRS 2.3.0d vs. Baseline 3)

9. Involve all disciplines of your organisation in the decision making process.

10. Consider a big learning curve has to be overcome and the selection of the best migration strategy/technical solution will require a collaborative approach with the suppliers and railway undertakers.

11. Only apply skilled labour with a sound knowledge and experience in the processes of ERMTS/ETCS and associated technology (IT, Telecom, etc.) and an excellent record of references from similar projects.

12. Depending on the size of the project apply best-practice organisation principles to adapt to the different stages of the project (restructuring, revitalisation, reframing) and business process re-engineering measures (standardised process and risk analyses).

13. ERTMS is more than infrastructure. The ERTMS features three main components, ETCS (Rolling stock), GSM-R and traffic management (Control Centre). ERTMS cannot be deployed in isolation by just one of the actors involved. Apart from the technical and operational aspects the deployment of ERTMS impacts the organisation in terms of the more IT-based technology versus electro-mechanical systems. Special focus has to be put on the train-track integration (suppliers to provide prove of system reliability).

14. The actors, is it the rail company or the infrastructure manager need to co-ordinate their deployment strategy with the strategy of the other actors in the system (national safety / approval agencies, ministry bodies, telecom, etc.).

15. Success of the project is highly dependent on the close co-ordination of all work-streams starting from the railway authority, duty holders, national security agency, notified bodies, railway companies, infrastructure managers and cross-industry teams.

4. SYNTHESIS

More than 62,000 km of railway tracks and 7,500 vehicles are already running or contracted to be equipped with ERTMS. 38 nations are using ERTMS throughout the world. It can be stated, that ERTMS has become « the » global signalling standard.

In Switzerland introduction of ERTMS has led to improved punctuality and shorter travel times allowing the passage of 255 trains per day at 200 km/h, with a headway of 2 minutes between trains. This very high density section of the Bern - Zurich and Bern - Basel routes is the cornerstone of Switzerland's migration plan for implementation of ERTMS on the whole network.

Yet, the technological maturity of ERTMS is still in a mixed state, even though many projects have been realised so far. There are both some critical high level and many detailed application decisions that will impact on the railway network once the system is in service.

Applications on simple line and junctions without level crossings have reached full maturity and can be taken in service without facing major problems. SRS 3.0.0 will include special functions for the supervision of level crossings that support harmonisation of the rules.

For complex applications as medium and larger station areas the recorded experience is limited. Special applications have proved to be major cost drivers related to development and engineering costs and the risk mitigation measures associated with it.

The ERTMS baseline 2.3.0 was developed to ensure technical interoperability of the first border crossing lines with ERTMS. The baseline is considered stable for the placement of new contracts. All cross-border connections work where they exist (Belgium/Netherlands, Austria/Hungary). Trains run in complete interoperability on ETCS system Level 1 and 2 from Rotterdam along the German and Swiss networks to Genoa.

UNISIG has set up a clear process to collect the return of experience on Baseline 2 investments.

Next ERTMS baseline 3.x.x has been issued in 2012 in order to enable the use of ERTMS on conventional corridors and networks. UNISIG has upgraded and delivered 26 subsets for Baseline 3. Backward compatibility with 2.3.0d to secure the investments made. Some suppliers claim to have SRS baseline 3 functions already available on their equipment for short development and delivery time.

The factors to be considered for migrating to ERTMS/ETCS are different in every country/state. For this reason there is no common strategy. Each country will give a different rating to the factors like Interoperability, percentage of cross-border traffic, necessity to increase line speeds, increased capacity, increased safety, renewal of life-expired infrastructure, renewal/ refurbishment of life-expired rolling stock, recovery of existing Train Protection systems and other aspects.

It is a big step to go from national legacy systems to a full cab signalling system that will fundamentally alter the way the system is operated. Railway organisations will therefore need to involve all stakeholders in the decision making process including Corporate Safety, Safeworking, Train Operations, Train Crewing, Drivers, Train Control, Engineering Standards, Rolling Stock, Signalling Maintenance and future Capacity Planning.

Business cases for ERTMS exist today based on one side on the level of maturity achieved today and on the other side tasking into account the strategy of the suppliers in the signalling market and the benefits of ERTMS in the long term.

APPENDIX 1: OPERATIONAL MATURITY ISSUES

A . SHUNTING

ETCS includes a shunting mode of operation where a train is permitted to move freely with little supervision from the infrastructure. Whereas this is quite useful in dedicated depots and yards, it is equally risky in train traffic areas. Even if most of traditional shunting is substituted by supervised cab-forward driving, a need remains for operation of freight trains and work vehicles that may be "propelling", i.e. *not* operating cab-forward.

The operational rules confine the use of shunting mode to permanent/temporary shunting areas, routes for shunting and possessions. The infrastructure supports this insofar track allocated to shunting operations will not be allocated to train traffic. Delimitation of a shunting area, shunting route or possession is primarily done by the available ETCS stop marker boards. However, the concept presents a number of challenges.

1) As ETCS stop marker boards must always be respected, shunting areas, shunting routes and possessions should avoid marker boards *within* the area/route, because they would impede fluent operation and increase workload on the person responsible for issuing permissions to pass such marker boards. But at the same time there may be a need for sub-dividing platform and yard tracks by ETCS stop marker boards due to cross-overs half-way and/or "two trains at one platform" operation.

2) It shall be possible to define possessions everywhere. The risk of a train overrunning limits in error may need to be mitigated by extra safety distances, either making use of overlaps already present, or by extending the area by extra "buffer" areas. From an engineering rules perspective it is quite difficult to solve this issue without setting severe constraints on other traffic. ETCS includes certain "trip balise" solutions to limit overrun which have been found inadequate, because they only affect the traction unit that may be far behind propelled vehicles.

3) Entry into a shunting area or a possession may use the option of changing to shunting mode at a further location, i.e. entering shunting mode "on the fly". From an operational rules perspective, this may lead to certain ambiguities. When operating in full supervision mode, the train will usually not enter an occupied track, but a shunting area may be occupied. For this reason the driver needs to acknowledge change to shunting mode before actually reaching the area. If this takes place early, the train will be in shunting mode while not yet in the area. If this takes place late it cannot be assured that the train is brought timely to a standstill if the train enters the area in error. A more consistent solution might be to enforce on-sight mode prior to entering shunting mode – as this would but responsibility on the driver to a higher state of vigilance while the train is still supervised – but this adds to complexity, technically as well as operationally.

4) Entry into a shunting route requires the train to be in shunting mode in advance, because it would be unsafe to assign shunting mode to a vehicle in train traffic area. But this implies that a shunting route would need an extension, or a joined shunting area, "under the train". From an operational rules perspective, this may lead to certain ambiguities, e.g. shunting mode assigned to a non-intended vehicle (being in the same area, but not ready to enter the particular route).

5) ETCS provides no means for ensuring that shunting mode is revoked on-board – or the shunting vehicle has vacated the area – when a shunting area, shunting route or possession is taken back into train traffic area. This has to be managed by procedures, and it may be seen as a decrease in safety compared to present-day "shunting signal" concepts. A particular concern is when two or more vehicles have been granted shunting in the same area or are operating across several areas. At take back there is a certain risk of overlooking the second vehicle or assuming it to be in a different location leaving a vehicle in shunting mode within a train traffic area.

B . REVERSING

ETCS includes a reversing mode of operation where a train is permitted to move backwards while the driver is still at the cab-forward desk. The original purpose of this mode was to support certain emergencies, e.g. tunnel evacuation. it is little suited for other purposes. For this reason, the operational concept prepared did not foresee the implementation of this mode. The functional requirements specifically ruled it out.

However, there are "everyday" situations calling for reversing, like a train overrunning a platform or being routed in the wrong direction. Presently, the best operational method is for the driver to occupy the opposite cab, and thus proceed in forward direction. This is a time consuming process, and the option is not available for all train compositions. The staff responsible mode has certain limitations on reverse operation and the shunting mode has certain drawbacks regarding safety, because train is not supervised. No satisfactory solution to this issue yet has been found and decided upon.

C . DEGRADED WORKING

A type of balise can be placed in the infrastructure in support of degraded working, such that a train in staff responsible mode will be tripped if passing the balise in error. Utilisation of such specific balises would have called for a significant increase in the amount of physical elements in the tracks. This would result in increased investment and maintenance costs. Consequently, it was at an early stage decided to exclude the use of specific balises supporting degraded working.

As a consequence of this decision, no technical barriers exist for degraded working and safety relies solely on manual procedures. To satisfy the safety target this calls for a strict protocol relying on ETCS stop marker boards and this in turn reduces capacity during degraded working. The advantage is a reduction in complexity of operational rules as all degraded scenarios are treated the same way. There will be no difference between a scenario with failed infrastructure and a scenario with failed train onboard equipment. The disadvantage is a higher reliance on ETCS stop marker boards, and thus the introduction of operational trade-offs between placing ETCS stop marker boards in support of degraded working and in support of shunting operation, possession management and the change in supervised driving mode profiles into lower modes of supervision.

D . ON-SIGHT MODE

The change from on-sight mode profile to full supervision mode is configurable. The different solutions have various implications for operation and safety:

- From ETCS stop marker board to ETCS stop marker board – with upgrade window
- From axle counter to axle counter covering safety distance – with upgrade window
- From axle counter to axle counter covering safety distance – without upgrade window
- From axle counter to axle counter covering safety distance – with track ahead free confirmation from driver

With the use of an upgrade window, the train can automatically switch back to full supervision mode when it is close to the end of an on-sight-route, provided the next route segment is clear for full supervision mode. This means that the train is relieved of on-sight restrictions and can increase speed before the end of a faulty train detection section. Ending the mode profile before the ETCS stop marker board, and not at the end of the train detection section, introduces the uncertainty of hidden "ghost" vehicles between these two locations. The same uncertainty can be argued against the use of an upgrade window after the ETCS stop marker board, but still before the end of the section.

Without the use of an upgrade window, the switch back to full supervision mode happens at the end of the on-sight mode profile, i.e. when the train front is beyond the axle

counter. This means that the train can only increase speed after passing the entire restriction. However, if an upgrade window is not used there will be an operational and a capacity impact. This can to some extent be improved by allowing the on-Sight mode profile to end at the end of a failing train detection section even if there is no ETCS stop marker board at this location, i.e. "within" a route. However, at the same time this introduces a safety concern regarding cases where another section in the route becomes occupied, or failing, and the on-sight mode profile cannot be updated accordingly.

The use of Track Ahead Free is not compliant with the current functional requirements, as it would put responsibility on the driver to acknowledge that the track is free up to the axle counter (wheel sensor). This is not a reference point for him, as he can see only the ETCS stop marker board which is typically located 50 m before.

The choice of configuration is further constrained by ETCS not allowing overlapping of on-sight mode profiles. This means that a concept that requires different solutions for the last route segment with on-sight mode profile, and a sequence of route segments with on-sight mode profile, would call for increasingly complex engineering.

It may be argued that on-sight is a kind of degraded mode, and therefore the solution has little consequence for overall performance. But on-sight mode is expected to be used frequently, not only for joining of trains, but also for splitting of trains, and other start-of-mission cases, where the train cannot be granted full supervision until it has passed into the next section. The use of written order "to get the train started" is undesired.

E . SHORTENING OF MOVEMENT AUTHORITIES AND EMERGENCY STOP

ETCS allows for using different functionality for different scenarios involving recalling already issued movement authorities.

For the scenario of recalling a movement authority for dispatching purposes, e.g. wanting to change routing into an alternative platform, a functionality of cooperative shortening exists. This allows the train to reject the request for a shortening of a movement authority where this would otherwise result in a brake intervention. For all scenarios where the recalling of a movement authority are motivated by convenience and not by safety the cooperative shortening functionality are used.

For emergency scenarios ETCS allows both conditional and unconditional emergency stop. The choice of functionality relies on analysis of applicable failure scenarios. Where an emergency situation has been detected for a specific train or area it is easy to determine the use of unconditional emergency stop, as the use of conditional emergency stop will not affect a train that has already passed a location of danger. There are however scenarios where the use of unconditional emergency stop are undesirable. Examples of using conditional emergency stop are as protection from conflicting movement of vehicles where flank protection is missing, if it cannot be determined if track occupancy detection is caused by the train travelling the route or by an unauthorised movement from the flank. The use of conditional emergency stop can be used to determine if the train has already passed the danger point. Other examples are where the emergency is at a further defined location, and thus it is unnecessary to cause an immediate emergency brake application e.g. for alarms from hot axle box detectors.

Finally, ETCS allows a new movement authority to override a previous movement authority. The timing of this functionality is not guaranteed by ETCS, and thus it should not be used for emergency scenarios, but only with manual route release, where a route is released a given time after the new and shorter movement authority has been issued.